EE 113D – Digital Signal Processing Design

Mini Project 2: Vowel Recognition

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Objective:

In this project, we learned how to build up the recognition vowel which distinguish between 4 different vowel sounds “ah”, “eh”, “ee” and “oo”. To accomplish this. We implemented the features of a vowel by computing its Mel Frequency Cepstral Coefficients (MFCCs). We then built a data base for the vowels and used a machine learning approach to update the data base as well as recognize incoming vowel sound. The machine learning allows the program to recognize the proper value with different gender vowel as long as we collected enough data of different gender. The main goal was for the program to be able to train itself through machine learning. When it had trained enough it would be able to distinguish between different vowels with different gender.

Discussion:

we recorded the input signals then they were stored in an array. Next, we extracted the features of these vowel sound. MFCC came up with a feature vector with 13 elements for each frame. we used the Fourier transform and squared its magnitude to collect values for the DFT array. We calculated the energy value of each of the 26 triangles that are in the filer bank. For each of 26 filters in 2 loops, we calculated a point on the first filter in the bank, then we multiplied it by power spectral density and stored it in an energy array. After obtaining 26 separate energy arrays, we summed up each array individually to obtain a total energy number for each triangle, which we were stored in one 26-element array. We then took the logarithm of each output energy. To form 13-elements MFCC array, we then took the discrete cosine transform to this array. In the next step, we were collecting 13 of 13-elements MFCC data base for each vowel and used a machine learning approach to update the data base as well as recognize incoming vowel sound. After using MATLAB to update data base, we extracted all the data from the MATLAB to the H7 board. Based on the MATLAB generated function, we implemented the trained shallow neural network in CCS. First step, we preprocessed our MFCC by performing element-wise subtraction, element-wise multiplication, element-wise addition. Similar to the mini-project 1, we implemented layer, hidden layer, and Relu function. In this project , we successfully implemented our function and able to recognize all the vowels with different gender.

Table 2: A table of the 26 Log-Energy X's for Each Monophthong

vowel	data
aa	9.8626,9.8564,9.9238,10.1003,10.4668,10.5876,10.0357,10.0070,10.5400,10.3869,9.1568,8.5976,8.4585,8.6402,9.2404,8.9277,8.1386,8.1777,8.1164,8.0294,7.9512,8.1243,8.1224,8.2217,8.2253,8.2653
	0.999605,0.000026,0.000012,0.000357
eh	9.9092,9.9287,10.1324,10.5761,10.2119,9.3474,8.9344,8.8003,8.6375,9.0811,9.5259,9.5561,9.2950,9.0640,9.2630,8.8823,8.1975,7.9604,8.0152,7.9209,8.0237,8.2198,8.0936,8.1602,8.1142,8.1665
	0.000013,0.999530,0.000012,0.000446
ee	11.0308,10.8206,9.9603,9.1450,8.1581,7.9174,7.6036,7.6602,7.6648,7.9560,7.7729,7.8657,7.9863,8.5679,9.2511,8.9147,8.8827,8.6824,8.2041,8.0320,8.1256,7.8870,8.0020,8.2493,8.2868,8.3038
	0.000036,0.000036,0.999065,0.000864
oo	10.6042,11.1649,10.2905,10.0347,9.5041,8.1156,7.7761,7.9350,7.4299,7.8163,7.8628,7.7889,7.8898,8.0955,8.0405,7.7275,7.9293,7.9576,7.9846,7.9684,7.9136,7.9920,7.9771,8.1450,8.3170,8.1770
	0.000148,0.000441,0.000148,0.999263

Table 2: A Table of the 13 Mel-Frequencies for Each of the Monophthongs

vowel	Data
	11.833012,5.592910,-1.315691,-1.390284,-2.489019,0.838294,2.478174,-0.021258,-2.465204,0.237384,2.596188,1.205611,-0.263975
	10.616450,4.803926,-0.716815,-1.708331,-1.562019,0.356564,0.711921,0.227986,-1.882501,1.184489,3.346510,1.302211,-0.194634
	12.189318,3.913352,-1.612746,-1.419376,-1.489627,0.778568,1.396049,-0.963704,-1.841895,1.508658,2.836232,1.375172,-0.577019
	9.791028,5.444975,-0.635390,-1.579468,-0.130415,-0.048584,-0.362833,-0.645890,-1.072111,1.120447,2.814655,2.616371,0.084404
	12.008522,3.794146,-2.454976,-1.394946,-0.752783,0.497459,1.371432,-0.283805,-1.761151,0.655368,3.351585,1.985256,-0.328743
aa	11.101966,0.437746,-4.829045,-2.779444,-2.857276,-2.773339,-1.805879,-3.174407,-1.776120,-1.986372,-0.072720,-0.388491,-0.907509
	10.866765,-0.416656,-5.493237,-1.800815,-3.543526,-2.092554,-1.114052,-2.562987,-1.857376,-2.205367,-0.693101,-0.400742,-0.009697
	7.570477,-3.849331,-2.544340,-4.731182,-3.492097,0.726637,2.401147,2.805935,-4.166147,-1.412564,0.745014,-2.861816,0.854143
	9.730055,-3.682895,-6.029683,-4.767819,-1.660149,-0.216427,1.464566,4.086639,-0.757033,-0.362725,-0.592637,-0.784478,2.419704
	6.133532,-7.565815,-1.426919,-1.783378,1.041963,-2.702809,1.456051,0.087044,-3.571191,2.656803,0.593850,-1.377919,-0.553677
	7.290484,-4.119120,-1.855465,-1.694275,1.633771,0.481659,3.795984,2.241274,-2.342456,0.411933,2.215962,2.241822,-1.385041
	7.337941,-4.689762,-1.404761,-2.495465,3.659612,0.651177,3.112662,3.044468,-3.136260,0.118947,2.339777,2.161105,-1.070508
	6.032681,-4.313091,-1.563935,-0.783840,2.101650,1.619926,2.189746,2.631859,-2.571166,0.279732,2.174745,0.657423,-1.236052
	8.543486,2.783047,2.843860,2.238290,-2.720429,-4.148986,-0.868777,-0.111549,-1.006254,1.110655,1.287407,-0.205677,0.808101
	11.647715,2.823330,1.839114,3.911843,-1.967215,-2.923046,-1.119107,-1.190319,-1.778363,0.523811,1.051454,-0.423452,1.091785
eh	8.904867,3.220271,2.385431,3.439453,-1.559862,-3.097474,-0.844411,-0.734509,-0.546945,1.267569,0.996859,-0.483272,0.205750
	9.085696,3.606338,2.159988,2.596899,-1.049521,-3.537621,-1.267143,-0.179583,-0.957289,0.284937,0.344663,-0.318587,0.992041
	5.520182,-7.511497,2.290657,6.265613,1.938981,-3.722482,-2.103341,1.559474,-0.213304,-0.308943,-0.055632,-1.983419,0.891529
	6.512071,-6.932247,1.171036,7.583298,1.458490,-4.160167,-2.717134,-0.096423,-0.028728,0.617058,0.478922,-0.343077,-0.117007
	2.144272,-7.249897,5.618129,7.149307,3.377418,-2.423842,-2.983356,0.655371,-1.060499,-0.671443,-0.661472,-0.186877,-0.509111
	2.519722,-7.039535,5.783281,8.560410,3.920175,-3.075402,-0.911127,1.903502,-1.191564,-0.429899,-3.536287,-0.401859,-0.658169
	5.333042,-6.909954,3.191969,5.756316,2.982547,-2.141290,-2.612970,2.314631,-0.612047,2.205968,1.373915,-2.939769,3.083186
	5.696565,-6.508464,2.812523,5.554596,3.257472,-1.906018,-1.930064,2.063851,-0.666182,2.075656,0.752416,-2.579487,3.274366
	7.909588,-9.124611,-1.417787,2.859397,-2.109114,-6.210202,-4.350934,-1.048942,-5.137199,-2.608261,-0.944351,-3.374547,1.808543
	8.161733,-9.003709,-2.689801,3.513540,-2.389680,-6.172715,-4.025496,-1.923338,-4.896433,-1.715904,-1.279477,-4.698342,1.740204
	7.784204,-8.795362,-2.199255,3.452112,-2.355673,-5.710978,-4.945360,-1.926654,-5.050261,-1.790327,-1.756760,-4.130778,1.745982
	4.648556,4.685560,10.638650,8.667466,1.256740,2.873481,5.106165,0.917521,-1.992633,0.067966,0.485589,-1.352632,-1.913671
	4.247813,5.129107,8.933463,8.051679,2.545943,1.725069,5.001406,1.462664,-2.496064,-0.624694,1.445079,-1.574011,-1.635171
	5.365000,7.497525,10.561935,7.386562,2.117274,2.916430,2.595085,1.801883,-1.377903,-0.758339,1.031719,-0.943479,-2.371092
	4.566232,5.302253,8.659989,7.143747,1.275461,2.509477,5.544699,2.952533,-0.458968,0.775114,2.289543,-0.205337,-1.766958
ee	4.942443,2.903984,9.646175,9.253586,0.922948,2.251748,4.582942,1.921239,-1.985530,-0.675784,1.989390,0.068414,-1.947817
	1.421274,-0.124214,2.457213,3.994054,0.347417,-0.643637,-0.510553,0.535747,0.364414,-0.943182,-0.082035,-0.229101,-0.492216
	-2.846788,-3.236730,8.011587,5.165356,-4.205059,3.755736,3.872205,1.522716,-2.094283,0.903512,2.577258,-4.229032,-0.631823
	-3.140387,-2.576777,7.647876,5.200269,-3.964281,2.183137,2.777593,0.106814,-1.744452,0.760793,2.899977,-2.525305,0.525086
	-3.242823,-1.488309,7.781851,3.875745,-2.888322,0.209937,1.911114,0.344980,-4.557782,-0.722394,3.068521,-3.617507,-0.658767
	4.417865,1.041363,7.304526,0.565329,-6.913661,0.444578,0.722658,-5.535037,-3.600170,-0.578141,-3.511886,-4.169847,-1.135833
	5.960113,2.153596,5.649854,1.503270,-5.505346,0.870181,2.700850,-4.697691,-4.350307,-1.593038,-4.614684,-4.653672,-1.065567
	4.385904,1.661310,6.642075,1.219334,-6.120277,1.189596,1.189825,-5.414230,-3.467471,-1.004703,-5.191547,-5.089184,-0.460241
	-1.993594,-3.767250,6.049012,5.286259,-0.694401,0.035573,2.210438,-1.082673,2.784463,-1.689736,-0.072343,0.408399,-0.484452
	10.346232,12.233593,8.648509,5.460092,1.634119,-0.624589,-2.440874,-1.951124,-0.491675,-0.315428,0.059161,0.349340,0.315908
	9.867177,11.986290,8.050630,4.019799,1.010418,-0.822381,-1.024837,-0.892622,-0.543807,0.082632,0.188408,1.074731,-0.289543
	10.060159,11.380287,8.029881,4.943376,1.327972,-0.237076,-1.409153,-0.876935,-1.339688,0.015311,-0.505108,-0.906720,0.179072
	10.392937,12.116968,7.738440,4.354136,1.995270,-0.601153,-1.465523,-1.455807,-0.944669,-0.555398,-0.024626,-0.063677,-0.305122
	9.379949,12.095263,7.642860,4.396228,1.206631,-0.584109,-0.943730,-0.975878,-0.678149,-1.203050,-0.252173,0.092734,0.249445
oo	9.219115,5.673684,0.507254,-0.653466,-2.198180,-2.231988,-2.510091,-2.190170,-3.548626,-3.163415,-2.368532,-4.238675,-3.885099
	9.041712,6.494777,1.422000,-0.257268,-1.802740,-2.604304,-2.064077,-1.767192,-2.395412,-2.626801,-2.797481,-3.342952,-3.604564
	7.940132,5.907035,1.817017,0.127031,-1.875466,-1.853045,-1.996973,-1.817977,-2.104103,-2.735722,-2.960872,-3.470280,-3.510604
	10.761856,3.811907,0.190747,-3.135863,1.040667,2.846665,2.009550,1.518910,-4.530840,-3.128123,-0.280720,-4.008136,-2.529209
	9.316811,3.252670,-0.275379,-2.951701,-0.652408,1.527632,2.860274,2.424204,-4.700265,-3.593549,-2.233932,-3.548536,-1.085584
	11.395627,2.529225,1.711151,3.065829,-1.754385,-2.118188,1.240185,0.933241,-1.672479,-1.383647,-1.008675,-1.117679,-3.239131
	11.483318,3.141224,1.647445,2.001385,-2.120577,-2.079834,0.448360,1.094413,-1.769408,-1.783112,-0.016464,-1.509926,-3.372652
	11.500233,4.173512,2.600270,-1.163451,-2.187120,-0.322853,-0.494265,0.080640,0.621810,-0.901523,0.190435,-2.230318,-1.544233

Figure 1: vowel “aa”

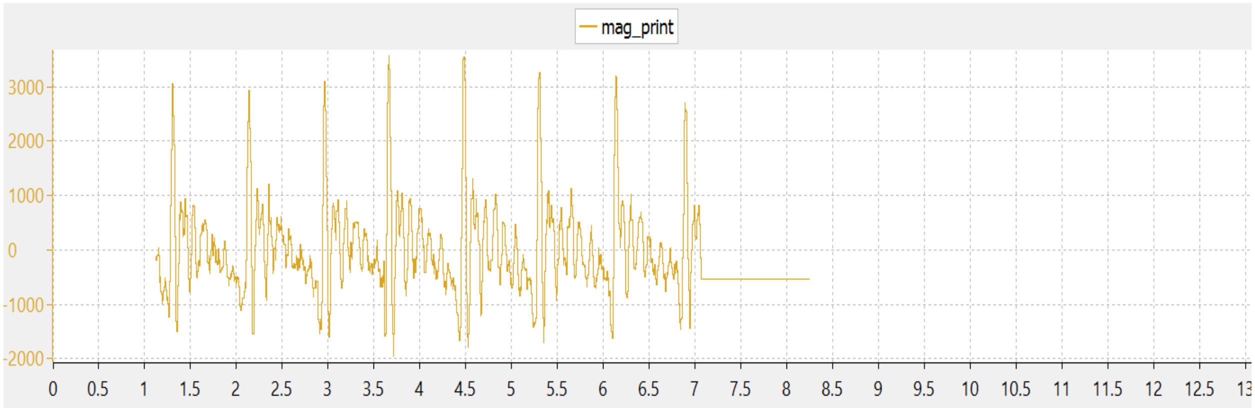

Figure 2: vowel “eh”

Figure 3:vowel “ee”

Figure 4:vowel “oo”

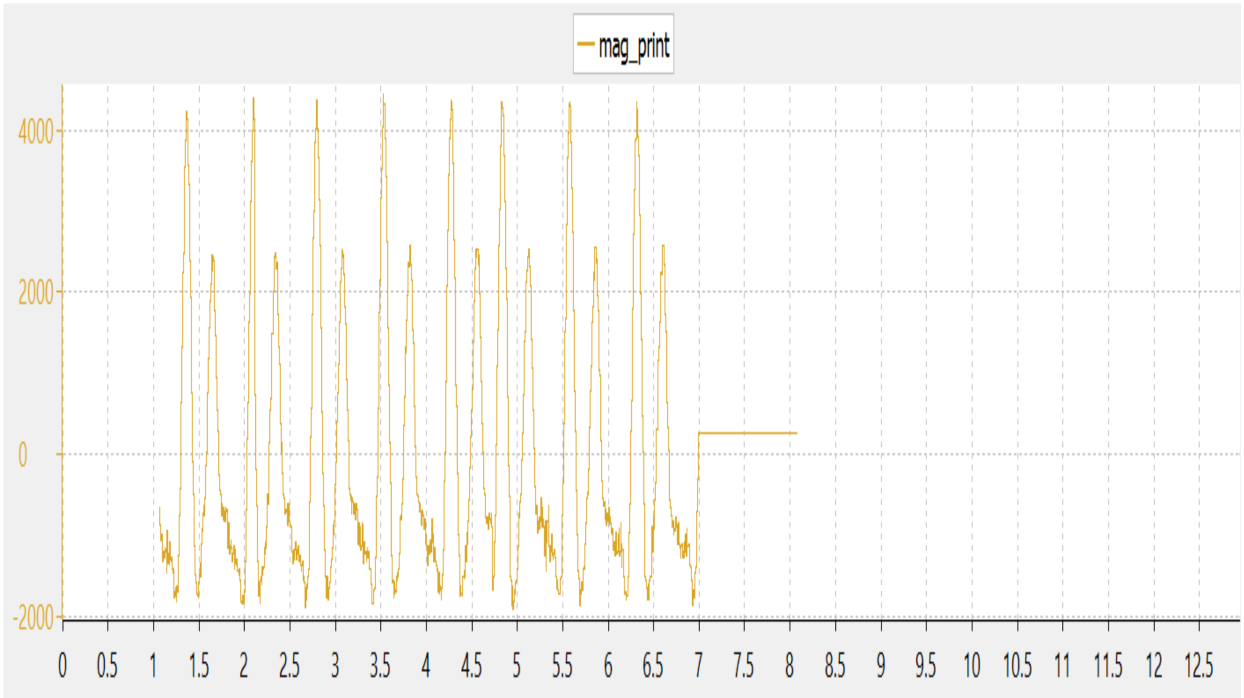

Figure 5: Diagram

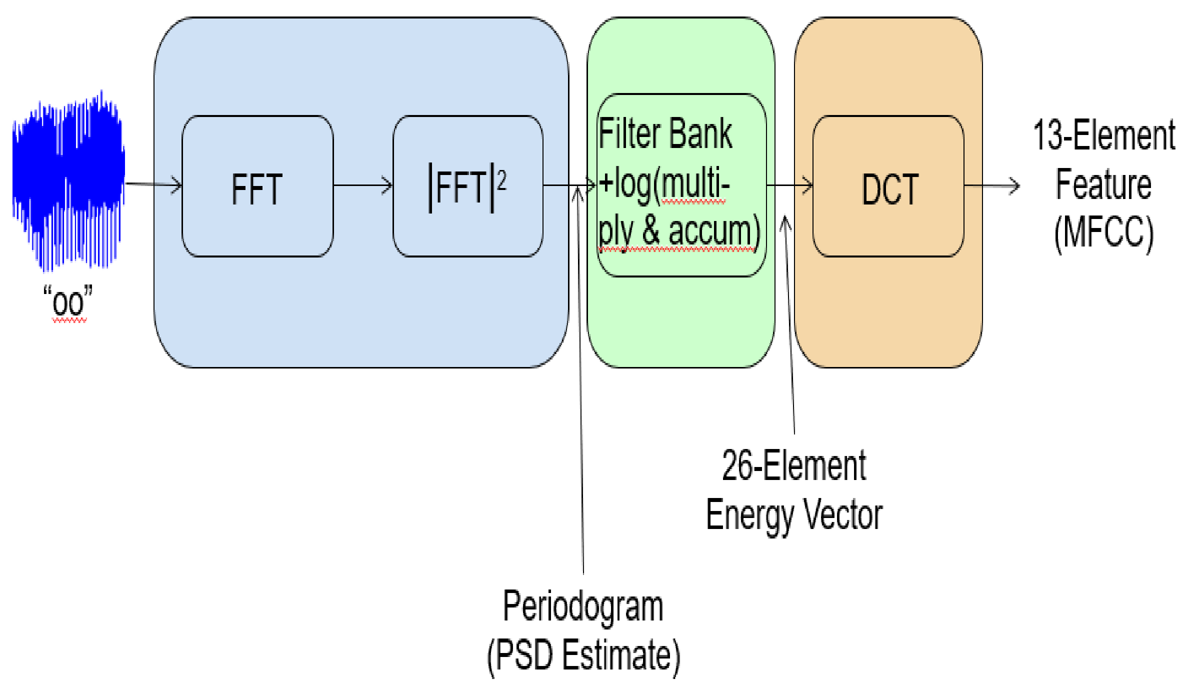

Figure 6: Validation Accuracy and Test Accuracy from Matlab

Table 3: A Table of Recognition Accuracies for Each of the Four Required Monophthongs

/aa/	/eh/	/ee/	/oo/	index
0.997815	0.000034	0.000031	0.002121	1
0.991053	0.000159	0.000025	0.008763	2
0.990721	0.003927	0.000079	0.005273	3
0.999665	0.000014	0.000003	0.000317	4
0.999073	0.000659	0.000009	0.000259	5
0.000004	0.999949	0.000004	0.000043	6
0.000001	0.999996	0.000001	0.000002	7
0.000042	0.998773	0.000042	0.001143	8
0.000001	0.999994	0.000001	0.000004	9
0.000134	0.997219	0.000019	0.002628	10
0.000054	0.000054	0.994711	0.005180	11
0.000016	0.000016	0.999796	0.000172	12
0.000006	0.000006	0.999753	0.000236	13
0.000006	0.000006	0.999865	0.000123	14
0.000037	0.000037	0.998272	0.001653	15
0.000083	0.001399	0.000083	0.998435	16
0.000160	0.004279	0.000160	0.995401	17
0.000137	0.001605	0.000137	0.998120	18
0.000415	0.000415	0.000600	0.998570	19
0.000696	0.017812	0.000696	0.980795	20